Appendix C. Compressed Air

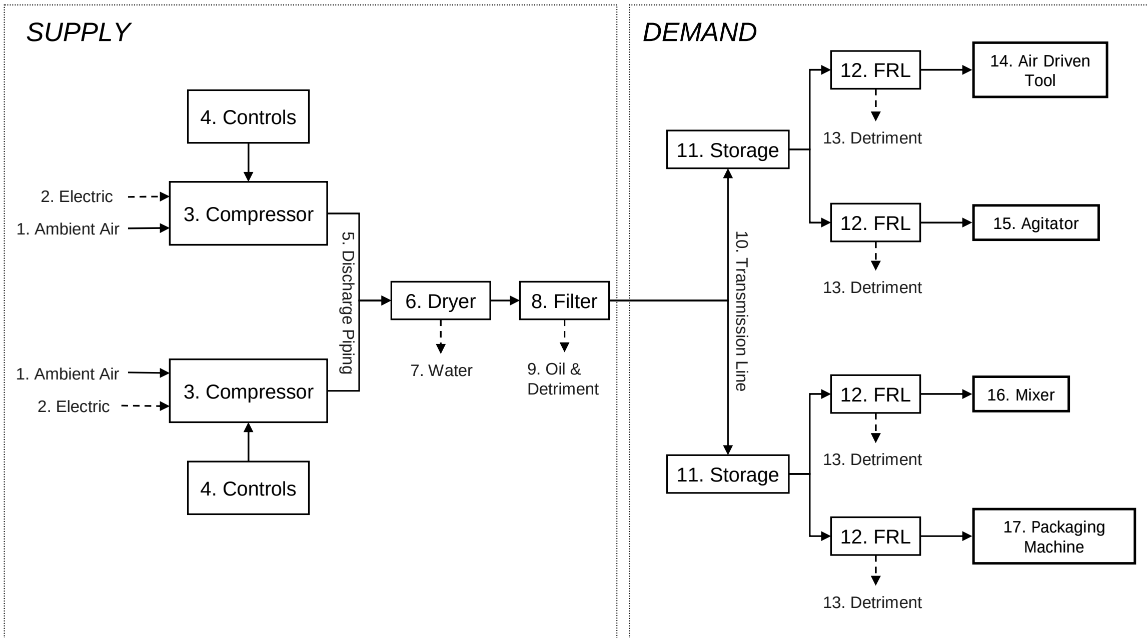

Figure C.1 – Compressed air system layout

SYSTEM OVERVIEW (REFER TO FIGURE C.1 ABOVE)

Compressed air systems are often operated 24 hours a day, seven days a week, 52 weeks of the year. Therefore, it should not be surprising that, according to the U.S. Department of Energy's Office of Industrial Technology (OIT), compressed air systems account for $1.5 billion in energy costs per year. OIT has also found that optimizing compressed air systems can improve energy efficiency by 20 to 50 percent!

A compressed air system has both a supply and demand side. The supply side consists of all of the equipment that conditions air, and the demand side is comprised of the remaining components. The primary components of a compressed air system, as shown in Figure C.1, are:

- compressor (3)
- controls (4)
- discharge piping and transmission lines (5 and 11)
- dryer (6)
- filter (8)
- storage tank (10)
- filter, regulator, lubricator, also known as FRL (12)
- compressed air-powered equipment (14-17)

The compressors (3) are the largest energy-consuming equipment in the compressed air system. Compressors are divided into two basic types: dynamic and positive displacement. Most industries use positive displacement compressors in the form of either reciprocating or rotary-screw compressors. Compressor controls (4) use many different techniques depending on the demand for the plant. Good controls are necessary for a well-managed system.

Because of the wide variety of business sizes and applications, air compressors used by food processors typically vary in power from 20 to 300 hp. The compressor is generally powered by a 460-volt A/C power source (1). Maximum pressure at the compressor also varies but usually ranges from 90 to 130 psi.

The ambient air (2) that is pulled into the compressor contains some amount of water vapor. Most of this water (7) is removed in the dryer (6) after the air is compressed. Moisture that remains in the system can cause equipment problems and decrease efficiency. Moist air can account for rust and scale build-up in transmission lines (11). It can also cause maintenance problems on equipment (14-17) or wash away important lubricants.

The filter (8) removes any oil and debris from the compressed air. A dirty line can increase pressure losses on the transmission lines (11) and damage equipment.

Storage tanks (10) can be located in many places throughout a plant. Many experts recommend placing storage tanks close to the compressors and close to major demand areas. These tanks help match the supply of compressed air to the demand for it throughout the system. They also reduce unnecessary start-up by buffering the compressors from fluctuations in system pressure caused by frequently changing demand at the points of usage.

A series of discharge piping and transmission lines, some fixed and many flexible, connect the air-driven equipment to the air supply. It is common to have the air passing through an additional FRL (12) before entering the various air-driven equipment.

ENERGY SAVINGS OPPORTUNITIES AND RELATED BEST PRACTICES

In 1,285 energy audits of food processors conducted by the national network of Industrial Assessment Centers, the following were the most significant energy-related topics with regard to compressed air systems (significance is based on the combination of frequency of occurrence and dollars lost):

- air leaks
- system pressure
- intake air temperature
- compressor size
- compressor lubrication

Demand

<u>Air Leaks</u>

It is important to educate employees on the costs related to air leaks and improper uses of compressed air. One type of compressed air “leakage” that is often overlooked occurs when compressed air is provided without regulating the pressure. Different pieces of equipment require different pressures, and supplying compressed air above the minimum necessary pressure causes excess air flow and wastes energy. If regulators are installed, they should be adjusted to the appropriate pressure.

The recommended best practice for dealing with air leaks and improper uses of air is to implement a continuous program for locating and fixing leaks as well as identifying improper and unregulated uses of compressed air. To avoid having unqualified plant personnel adjust pressure regulators to their wide open position, it is recommended to install them out of the easy reach of operators.

Savings in energy costs will vary depending on the size of the compressed air system in a given facility. The following estimated savings are calculated for a "base system" consisting of two 100-hp, screw-type compressors generating 120 psi line pressure and operating 24 hours, seven days a week, 52 weeks a year. Marginal energy cost is $0.03/kWh, and marginal cost of demand is $75/kW-yr. For this base system, typical savings in energy usage ranged from $440 to $1,100, while demand cost savings varied from $1,560 to $3,900 per year. Total cost savings, therefore, ranged from $2,000 to $5,000 per year.

Supply

System Pressure

Common practice is to set system pressure relatively high. This is usually done with the good intent of keeping up with demand. By increasing line pressure, however, compressors increase energy usage and also increase compressed air consumption. Air leaks exacerbate this problem. Insufficient airflow is normally not caused by a problem in the supply side of a compressed air system (see Figure C.1), but it is instead a demand-side issue. For example, incorrect pipe sizing can cause a loss of system pressure. In such a case, it is necessary to increase pipe size or reduce the number of sharp bends in the piping.

The most recommended best practice for dealing with system pressure is actually to decrease pressure by small increments of about 5 psi at a time. Continue to reduce system pressure until the performance of the air-driven devices is adversely affected. Then slowly increase pressure back toward the previous setting until the lowest set point is found for the plant.

For a reduction of 5 psi on the "base system," estimated savings in energy usage are $790 per year, while demand cost savings are $225 per year. Total cost savings, therefore, are $1,015 per year.

Intake Air Temperature

Colder air is more dense and, therefore, requires less energy to compress. Studies show that reciprocating compressors can realize significant energy savings if outside air is ducted directly to the compressor air intake. It is common to use PVC piping for this purpose. Note that this is not the same as ducting outside air into the compressor area where it then mixes with the ambient air before it enters the compressor. In most cases, this greatly warms the colder, outside air, negating most of the benefit.

In Iowa, for two 100-hp reciprocating compressors, estimated savings in energy usage are approximately $2,140 per year while demand annual cost savings are $540. Therefore, the total annual cost savings are $2,680.

Compressor Controls

It is common to find oversized compressors in plants. This unnecessarily increases electrical demand and energy consumption. The recommended best practice for determining whether the compressor is properly sized is to use an electrical device that logs the power usage at the compressor. The data collected will show the load pattern on the compressor, thus helping to determine whether it is oversized.

Instead of purchasing a new compressor, one can also deal with oversized systems by installing a sequencer controller to manage the supply of compressed air. As loads vary, sequencer controllers allow the system to match the demand by operating the best equipment available for the load.

Multiple compressors may also be set to load and unload at different pressures in a “cascading” fashion. For example, if all compressors are loaded and the demand for air drops, system pressure will rise. At a preset point, one of the compressors will unload and subsequently shut down if demand for air stays low. If system pressure continues to rise, a second compressor will follow the same sequence. When the demand for compressed air increases, system pressure will drop and the compressors will be engaged in the reverse order. Variable frequency drives can also be installed in an air compressor to allow it to slow down and speed up according to the demand of air. Therefore, the compressor can modulate the production of air as needed. VFDs are further explained in the motors section of this document.

For the reduction of a 150-hp to a 100-hp screw compressor, estimated savings in energy usage are approximately $4,800 per year, while demand cost savings are about $1,370 per year. Total cost savings, therefore, are $6,170 per year.

Compressor Lubrication

The recommended best practice for compressor lubrication is to use synthetic lubricants to reduce friction. This will reduce the energy required by the compressor and has the added advantage of extending oil life to about three to four times that of premium mineral oils.

For the “base system,” estimated savings in energy usage are approximately $1,780 per year, while demand cost savings are $510 per year. Total cost savings, therefore, are $2,290 per year. The additional cost savings from adopting synthetic lubricants that results from the longer lifecycle with the associated reductions in the labor and materials involved will vary with your maintenance practices.

RESOURCES

Printed Material

Galitsky, C., Worrell, E. and Ruth, M., Energy Efficiency Improvement and Cost Saving Opportunities for the Corn Wet Milling Industry, EPA, 2003.

Martin, N., Worrell, E., Ruth, M., Price, L., Elliott, R.N., Shipley, A.M. and Thorne, J., Emerging Energy-Efficient Industrial Technologies, LBNL and ACEEE, 2000.

Mull, T.E., Practical Guide to Energy Management for Facilities Engineers and Managers, ASME, NY.

Okos, M., Rao, N., Drecher, S., Rode, M. and Kozac, J., Energy Usage in the Food Industry, ACEEE, 1998.

Rollins, J.P. ed., Compressed Air and Gas Handbook, Prentice-Hall, Inc. 5th ed, 1989.

Talbott, E.M., Compressed Air Systems: A Guidebook on Energy and Cost Savings, Fairmont Press, 2nd ed, 1993.

On-Line Tools

Compressed Air Challenge: www.compressedairchallenge.org

Food Engineering: The Magazine for Manufacturing Management: www.foodengineeringmag.com

Ingersoll Rand. (2001). Air Solutions Group.Compressed Air Systems Energy Reduction Basics: www.air.ingersoll-rand.com/NEW/pedwards.htm

Lawrence Berkeley National Laboratory, The Energy Analysis Department: http://eetd.lbl.gov/EA.html

Office of Industrial Technology (OIT), Best Practices: www.oit.doe.gov/bestpractices

Office of Industrial Technology (OIT), Software Tools: www.oit.doe.gov/bestpractices/software_tools.shtml

Organizations

British Compressed Air Society: www.britishcompressedairsociety.co.uk

Council of Industrial Boiler Owners (CIBO): www.cibo.org

Food and Drink Federation, Voice of the UK Food and Drink Manufacturing Industry: www.fdf.org.uk/home.aspx

Iowa State University Industrial Assessment Center (IAC): (515) 294-3080 or www.me.iastate.edu/iac